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(71) Applicant: **International Business Machines Corporation**
Old Orchard Road
Armonk, N.Y. 10504(US)

(72) Inventor: **Bonafino, Edward J.**
211 Patio Drive
Endwell, N.Y. 13760(US)
Inventor: **Carpenter, Richard W.**
189 Wyok Road
Johnson City, N.Y. 13790(US)
Inventor: **Lueck, Peter J.**
Heckenweg 40-4
W-7250 Leonberg(DE)
Inventor: **Summa, William J.**
1022 Elmwood Drive
Endwell, N.Y. 13760(US)
Inventor: **Wang, David W.**
800 Overbrook Drive
Vestal, N.Y. 13850(US)

(74) Representative: **Klocke, Peter, Dipl.-Ing.**
IBM Deutschland GmbH Patentwesen und
Urheberrecht Schönaicher Strasse 220
W-7030 Böblingen(DE)

(54) **Electronic circuit packages with tear resistant organic cores.**

(57) Disclosed are an electronic package and electronic package module. The module has a dielectric core (11) with surface circuitization (21) on at least one surface. The dielectric core is a composite having a thermoplastic layer (13) interposed between two separate layers (15, 17) of thermoset adhesive, as epoxy dicyanate adhesive. The thermoplastic layer is preferably a polyimide. The adhesive is preferably an epoxy or dicyanate adhesive, for example a homogeneous film of thermoset resin, or a fiber reinforced thermoset resin, such as a polytetrafluoroethylene reinforced epoxy or a glass fiber reinforced adhesive. The use of a thermoplastic polyimide layer interposed between adhesive layers provides a core that is particularly amenable to man-

ufacture as a thin core.

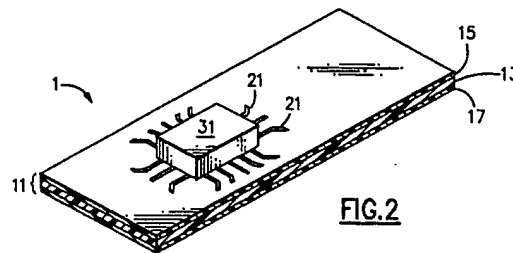


FIG.2

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This invention relates to microelectronic circuit packages, especially high I/O density packages.

The general structures and manufacturing processes for electronic packages are described in, for example, Donald P. Seraphim, Ronald Lasky, and Che-Yo Li, Principles of Electronic Packaging, McGraw-Hill Book Company, New York, New York, (1988), and Rao R. Tummala and Eugene J. Rymaszewski, Microelectronic Packaging Handbook, Van Nostrand Reinhold, New York, New York (1988), both of which are hereby incorporated herein by reference.

As described by Seraphim et al., and Tummala et al., an electronic circuit contains many individual electronic circuit components, e.g., thousands or even millions of individual resistors, capacitors, inductors, diodes, and transistors. These individual circuit components are interconnected to form the circuits, and the individual circuits are interconnected to form functional units. Power and signal distribution are done through these interconnections. The individual functional units require mechanical support and structural protection. The electrical circuits require electrical energy to function, and the removal of thermal energy to remain functional. Microelectronic packages, such as, chips, modules, circuit cards, and circuit boards, are used to protect, house, cool, and interconnect circuit components and circuits.

Within a single integrated circuit, circuit component to circuit component and circuit to circuit interconnection, heat dissipation, and mechanical protection are provided by an integrated circuit chip. The chip is referred to as the "zero order package." This chip or zero order package enclosed within its module is referred to as the first level of packaging.

There is at least one further level of packaging. The second level of packaging is the circuit card. A circuit card performs at least four functions. First, the circuit card is employed because the total required circuit or bit count to perform a desired function exceeds the bit count of the first level package, i.e., the chip, and multiple chips are required. Second, the circuit card provides for signal interconnection with other circuit elements. Third, the second level package, i.e., the circuit card, provides a site for components that are not readily integrated into the first level package, i.e., the chip or module. These components include, e.g., capacitors, precision resistors, inductors, electro-mechanical switches, optical couplers, and the like. Fourth, the second level package provides for thermal management, i.e., heat dissipation.

In most applications, and especially personal computers, high performance workstations, mid range computers, and main frame computers, there is a third level of packaging. This is the board level

package. The board contains connectors to accept a plurality of cards, circuitization to provide communication between the cards, I/O devices to provide external communication, and, frequently, sophisticated thermal management systems.

The basic process for polymer based composite package fabrication is described by George P. Schmitt, Bernd K. Appelt and Jeffrey T. Gotro, "Polymers and Polymer Based Composites for Electronic Applications" in Seraphim, Lasky, and Li, Principles of Electronic Packaging, pages 334-371, previously incorporated herein by reference, and by Donald P. Seraphim, Donald E. Barr, William T. Chen, George P. Schmitt, and Rao R. Tummala, "Printed Circuit Board Packaging" in Tummala and Rymaszewski, Microelectronics Packaging Handbook, pages 853-922, also previously incorporated herein by reference.

In the normal process for package fabrication a fibrous body, such as a non-woven mat or woven web, is impregnated with a laminating resin. This step includes coating the fibrous body with, for example, an epoxy resin solution, evaporating the solvents associated with the resin, and partially curing the resin. The partially cured resin is called a B-stage resin. The body of fibrous material and B stage resin is called a prepreg. The prepreg, which is easily handled and stable, may be cut into sheets for subsequent processing.

Typical resins used to form the prepreg include epoxy resins, cyanate ester resins, polyimides, hydrocarbon based resins, and fluoropolymers. One prepreg is the FR-4 prepreg. FR-4 is a fire retardant epoxy-glass cloth material, where the epoxy resin is the diglycidyl ether of 2,2' - bis(4-hydroxyphenyl) propane. This epoxy resin is also known as the diglycidyl ether of bisphenol-A, (DGEBA). The fire retardancy of the FR-4 prepreg is obtained by including approximately 15-20 weight percent bromine in the resin. This is done by partially substituting brominated DGEBA for the DGEBA.

Other epoxy resin formulations useful in providing prepreps include high functionality resins, such as epoxidized cresol novolacs, and epoxidized derivatives of triphenyl methane. The multifunctional epoxy resins are characterized by high glass transition temperatures, high thermal stability, and reduced moisture take up.

Still other epoxy resins are phenolic cured epoxies, as Ciba-Giegy RD86-170^(TM), Ciba-Giegy RD87-211^(TM), Ciba-Giegy RD87-212^(TM), Dow Quatrex^(R) 5010^(TM), Shell Epon^(R) 1151^(TM), and the like. These epoxies are mixtures of epoxies, with each epoxy having a functionality of at least 2, a phenolic curing agent with a functionality of at least 2, and an imidazole catalyst.

Cyanate ester resins are also used in forming prepreps. One type of cyanate ester resin includes

dicyanates mixed with methylene dianiline bis-maleimide. This product may be further blended with compatible epoxides to yield a laminate material. One such laminate material is a 50:45:5 (parts by weight) of epoxy: cyanate: maleimide. Typical of cyanate ester resins useful in forming preregs is the product of bisphenol-A dicyanate and epoxy, which polymerizes during lamination to form a crosslinked structure.

A still further class of materials useful in forming preregs for rigid multilayer boards are thermosetting polyimides. While thermosetting polyimides exhibit high water absorption, and high cost, they have good thermal properties and desirable mechanical properties. The preferred polyimides for prepreg use are addition products such as polyimides based on low molecular weight bis-maleimides.

By way of contrast, another type of polyimides, useful in forming stable, flexible films for flexible circuits are higher molecular weight polymers derived from dianhydrides and diamines.

One condensation polyimide based on diphenylene dianhydride is described in U.S. Patent 4,725,484. This patent describes a copolymer of 3,3',4,4'-biphenyltetracarboxylic anhydride and p-phenylene diamine, commercially known as Upilex^(R) S.

As noted above, the thermosetting polyimides may be reinforced with fibers to form rigid circuit boards. For example, thermosetting polyimide reinforced with polytetrafluoroethylene fibers are described in U.S. Patent 4,772,509.

The polyimide may be an intermediate layer of the core, between a substrate and the circuitization, as described, for example in U.S. Patent 4,705,720. This patent describes a flexible circuit package having a substrate, for example, a metallic substrate, fully encapsulated in a fully reacted, fully aromatic condensation type polyimide, to which the circuitization is joined by an adhesive. Kunding et al.'s adhesives include polyacrylates, polysulfones, epoxies, fluoropolymers, silicones, and butyl rubbers.

It is to be understood that processing of rigid boards and flexible circuits are very different manufacturing processes. In the case of manufacturing flexible circuits, subsequent processing includes circuitization, that is, the formation of a Cu signal pattern or power pattern on the film. Circuitization may be additive or subtractive. If a direct metal deposition process, such as chromium or copper sputtering is not used an adhesive is generally required between the circuitization and the flexible carrier film, especially in the case of polyimide films. Processing of flexible films is most often handled by roll to roll processes with a film width of ten inches or less.

Various adhesives have been reported for laminating copper circuitization to polyimide flexible circuit films. For example, U.S. Patent 4,634,631 describes the use of a microglass reinforced fluoropolymer as a dielectric adhesive for flexible polyimide circuits.

U.S. Patent 4,725,720, noted above, describe the use of adhesives such as polyacrylates, polysulfones, epoxies, fluoropolymers, silicones, and butyl rubbers to obtain adhesion between a polyimide layer and the circuitization.

U.S. Patent 4,725,504 describes the use of electroless Ni or Co to bond the Cu circuitization to a polyimide layer of a printed circuit board.

U.S. Patent 3,717,543 describes an adhesive for bonding polyimide to either a metal, as a circuitization layer, or to another polyimide film. The adhesive is an acrylic-epoxy copolymer, as an ammoniated acrylic and a low molecular weight epichlorohydrin bisphenol A copolymer.

U.S. Patent 3,904,813 describes an adhesive that is the reaction product of a carboxyl terminated polymer (as azelaic acid and neopentyl glycol) and a high molecular weight polymeric reaction product of bisphenol A and epichlorohydrin.

U.S. Patent 4,762,747 describes a printed circuit board having an adhesive layer on polyimide. The adhesive contains (1) an acrylonitrile, (2) an alkyl acrylate or methacrylate, (3) an oxirane containing polymerizing ethylenic monomer, (4) a hydroxyl or amide containing acrylate or methacrylate, and (5) styrene.

U.S. Patent 4,627,474 describes the use of an unreinforced epoxy adhesive to laminate metal foils to a polyimide film.

By way of contrast with the above described process for flexible circuits, the rigid multilayer composite printed circuit package is fabricated by interleaving cores (including signal cores, signal/signal cores, power cores, power/power cores, and signal/power cores) with additional sheets of prepreg, and surface circuitization. After lamination, hole drilling, photolithography, and plating processes are repeated, a rigid multilayer composite is obtained. The size of the rigid multilayer composite can reach 4336 square cm (60.96 cm by 71.12 cm) or more, with thicknesses of 6.25 mm (250 mils) or more.

The initial fabrication of the cores is carried out with large area laminates, i.e., up to thirty six inches or more, which are subsequently cut into smaller area assemblies. It is particularly important that these laminates neither delaminate nor tear during fabrication. Moreover, the complex sequence of these steps combined with the chemically and physically aggressive nature of many of these steps results in product compromise and loss. Moreover,, increasing clock rates require low

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impedance, low dielectric constant, thin cores. Thus, there is a clear need for a thin, rugged, thermally stable microelectronic package core, with matched coefficients of thermal expansion between the layers, that is fabricated of materials that are adapted for ease of manufacturing, including high peel strength, tear resistance and toughness while allowing the production of large surface area thin cores, i.e., less than 0.203 mm (8 mils) thick, by the use of conventional rigid core fabrication processes.

The invention as claimed is intended to provide a thin composite core structure with high electrical performance, and to provide this composite core structure in a microelectronic package adapted for ease of manufacturing in a conventional multilayer rigid board manufacturing environment, with tear resistance and toughness during lamination.

The electronic package module of the invention has a thin dielectric core with surface circuitization on at least one surface. The dielectric core is a laminate, that is, a composite, having a thermoplastic layer interposed between two separate layers of adhesive, characterized by good adhesion between the thermoplastic layer and the adhesive layers. The thermoplastic layer is preferably a polyimide, such as Upilex^(R) SGA^(TM). The adhesive is preferably a thermosetting adhesive, such as an epoxy adhesive or a cyanate ester adhesive, and is either a homogeneous epoxy or cyanate ester adhesive (such as, an unreinforced epoxy or cyanate ester adhesive layer) or a fiber reinforced adhesive (such as, a woven or non-woven glass fiber or polytetrafluorethylene reinforced epoxy or cyanate ester adhesive).

The circuit packages are characterized by individual cores or modules that combine flexibility and high tear resistance during fabrication, high tear resistance in the finished module, and efficient control of thermal expansion, with a module dielectric constant less than 3.8, a total module thickness less than 0.254 mm (10 mils), and a dimensional stability (growth and shrinkage) during lamination that is less than 200 parts per million.

Individual modules of the package have a dielectric core with surface circuitization on at least one surface thereof. The dielectric core of the module is a dielectric composite having an organic thermoplastic dielectric layer interposed between separate layers of thermosetting dielectric materials, for example epoxy prepreg dielectric or an adhesive dielectric film. The thermoplastic layer is preferably a polyimide, while the thermosetting dielectric may be a homogeneous (nonreinforced) adhesive film or a reinforced prepreg, for example, a woven or non-woven polytetrafluorethylene or a glass fiber reinforced epoxy prepreg.

It is an advantage of the invention to provide a

printed circuit thin core laminate of a thin, flexible thermoplastic film between adhesive layers, which may be homogeneous or reinforced, for example with woven or non-woven materials.

It is a further advantage the invention to provide a microelectronic package having toughness and tear resistance during fabrication while maintaining signal core organic thickness, from circuitization layer through the organic layers, to the opposite circuitization layer, that is less than 10 mils, and preferably less than 8 mils.

It is a further advantage of the invention to produce this thin core laminate on conventional thick core manufacturing apparatus.

It is a further advantage of the invention to provide a microelectronic package having a high interlaminar peel strength during fabrication.

It is a further advantage of the invention to provide a microelectronic package having an organic portion with a coefficient of thermal expansion of 8 to 25 parts per million per degree C that provides minimum mismatch of the individual layer coefficients of thermal expansion.

It is a still further advantage of the invention to provide a microelectronic package having a structure that avoids severe mismatches of component and layer coefficients of thermal expansion.

For a better understanding of the present invention, together with further objects and advantages, preferred embodiments of the invention are described in the following with reference to the accompanying drawings, in which:

Fig. 1 shows a cutaway plan view of simple signal core structure incorporating the basic laminated composite of the invention.

Fig. 2 is a partial cutaway perspective view of a simplified microelectronic package incorporating the signal core of Fig. 1.

Fig. 3 shows an alternative structure with two thermoplastic layers and three adhesive layers.

Fig. 4 shows an exploded view of a multilayer microelectronic package utilizing multiple iterations of the invention.

Fig. 5 shows an exploded view of an alternative multilayer microelectronic package utilizing multiple iterations of this invention to increase the dielectric thickness.

The microelectronic packages and package modules of the invention are characterized by very narrow spacing between circuitization layers, for example between adjacent signal plane layers, for example less than about 0.254 mm (10 mils) between signal plane layers, and between signal plane layers and adjacent power and ground core

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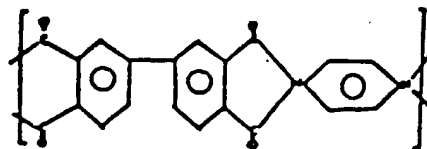
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layers. These packages are intended for high frequency applications. The narrow spacing between planes, translated into thin organic layers, results in fabrication problems, especially tearing and delamination, while the combination of the narrow spacing between signal planes and the anticipated high frequencies make dissipative effects a major design element of the package. The narrow interplanar spacing results in signal dissipation and distortion through the effect of the complex impedance, Z . Impedance converts the lost electrical energy into thermal energy, H , and the full range of thermal management issues, including losses in reliability and structural integrity (through mismatched coefficients of thermal expansion) become highly relevant.

One exemplification of the electronic package module of the invention is shown in Fig. 1 and a printed circuit board incorporating the electronic package module is shown in Fig. 2. The electronic package module 1 has a dielectric core 11 with surface circuitization 21 and an integrated circuit chip 31 on at least one surface thereof. The dielectric core 11 is a composite with a rugged thermoplastic layer 13, as a polyimide, interposed between two separate layers 15, 17 of an adhesive, as a polymeric resin, for example thermosetting epoxy resins, cyanate esters, polyimides, etc.

In a preferred exemplification the thermoplastic layer (13) is polyimide, and the adhesive layers 15, 17 are cyanate ester and epoxy polymers. This results in laminates of uniformly low coefficients of thermal expansion, i.e., the coefficient of thermal expansion approaches that of the copper circuitization, high dimensional stability, and ease of manufacturing, i.e., the absence of tearing, peeling, or delamination, especially when formed in large sheets, with at least one dimension in excess of eighteen inches.

The preferred thermoplastics are polyimides, with a particularly preferred polyimide being Upilex^(R) SGA^(TM). Polyimides, and especially Upilex^(R) SGA^(TM), have good moisture resistance, thermal properties, and desirable mechanical properties. These properties make them particularly advantageous for printed circuit board modules. The preferred polyimides for film use are condensation products, such as polyimides based on biphenylene dianhydrides. Especially preferred are copolymers derived from biphenylene dianhydrides and phenylene diamines. Especially preferred is the polyimide derived from 3,3',4,4'-biphenyl-tetracarboxylic anhydride and p-phenylene diamine. This copolymer has the structure depicted below:



Upilex^(R) S^(TM), which is a particularly preferred composition based upon this material, has a dielectric coefficient of 3.2 to 3.5, and a thermal decomposition temperature above about 600 degrees Centigrade. Typical epoxy adhesion to this material is about one pound per inch, making it particularly desirable for pre-preg boards.

When this particularly preferred polyimide is suitably modified by the incorporation of, for example, a silane coupling agent into the polymeric matrix, as is the case with Upilex^(R) SGA^(TM), the adhesion is above about 9 pound/inch. The silane coupling agent modified polyimide is especially preferred for the thermoplastic core material. The properties of the modified material makes it use especially advantageous in combination with the polyepoxide adhesives at polyimide thicknesses as low as 0.0203 mm (0.8 mils).

While the adhesive layer is referred to as an epoxy layer, other adhesives may be utilized, although epoxy adhesives are preferred. The epoxy layers 15,17 are either homogeneous (unreinforced) epoxy adhesive layers or fiber reinforced epoxy adhesive layers. The preferred epoxy is the polymeric reaction product of BrDGEBa and phenolics. These particularly preferred epoxies are mixtures of two or more epoxies, each of the epoxies in the mixture having a functionality of at least two, a phenolic curing agent, also with a functionality of not less than two, and an imidazole catalyst. These epoxies are sold by Ciba-Giegy under the designations RD86-170^(TM), RD87-211^(TM), and RD87-212^(TM), by Shell Chemical Co. under the designation EPON^(R) 1151^(TM), and by Dow Chemical Corp. under the designation Quatex^(R) 5010^(TM).

When the adhesive layers 15,17 are reinforced, the typical reinforcement materials include woven and non-woven fibers, and films made of glass fibers include glass fibers, such as woven fused quartz, E-glass fabric, S-glass, D-glass, and high silica glass, and organic fibers such as aramids (exemplified by Kevlar^(R) and Nomex^(R)), polyether ether ketone, aromatic polyesters, polybenzobisthiazole (PBZT), polybenzobisoxazole (PBO), fluorocarbons, as polytetrafluoroethylene, and graphite fibers.

Returning to the Figs., as clearly shown in Fig. 1 the composite 11 comprises a polyimide layer 13 interposed between two separate layers 15,17 of an

epoxy adhesive, such as an unreinforced epoxy adhesive or a glass fiber reinforced epoxy adhesive, or a woven or nonwoven polytetrafluoroethylene reinforced epoxy adhesive. In a particularly preferred exemplification shown in Fig. 1 the thickness of the polyimide thermoplastic layer 13 is from about 20.3 μm (0.8) to about 50.8 μm (2.0 mils), and the thicknesses of the epoxy adhesive layers 15, 17 are from about 2.54 μm (0.1) to about 20.3 μm (0.8 mils) in the case of homogeneous layers, and about 25.4 μm (1) to 101.6 μm (4 mils) in the case of prepreg layers. This range of thicknesses gives particularly desirable manufacturing properties, characterized by significantly reduced tearing, peeling, and delamination during fabrication. An alternative structure is shown in Fig. 3. In the structure shown in Fig. 3 three adhesive layers 315a, 315b, 315c and two thermoplastic layers 313a, 313b separate the circuitization layers 321a, 321b. In this structure the composite 311 comprises two polyimide layers 313a, 313b, each interposed between a pair of adhesive layers 315a and 315b, 315b and 315c of epoxy, including polytetrafluoroethylene reinforced epoxy and glass reinforced epoxy. In the exemplification shown in Fig. 3 the thickness of each of the polyimide thermoplastic layers 313a, 313b is from about 20.3 μm (0.8) to about 50.8 μm (2.0 mils), and the thicknesses of the three epoxy layers 315a, 315b, 315c are from about 2.54 μm (0.1) to about 20.3 μm (0.8 mils) in the case of homogeneous layers, and about 25.4 μm (1) to 101.6 μm (4 mils) in the case of prepreg.

Fig. 4 shows a multilayer structure incorporating the thin core 411a, 411b of the invention. Specifically, the structure shown in Fig. 4 includes two signal cores 411a, 411b. Each signal core 411a, 411b has two circuitization layers 421aa and 421ab; 421ba and 421bb and may have either the single thermoplastic layer type of structure shown in Fig. 1 or the multiple thermoplastic layer type of structure shown in Fig. 3.

The two signal cores 411a, 411b are separated from each other by two adhesive layers 415a, 415b and one thermoplastic layer 417, while each of the power layers 423a, 423b is separated from the adjacent signal core 411a, 411b by two adhesive layers 417aa, 417ab; 417ba, 417bb with a thermoplastic layer 413a, 413b therebetween. In the exemplification shown in Fig. 4 the thickness of each of the polyimide thermoplastic layers 413a, 413b is from about 20.3 μm (0.8) to about 50.8 μm (2.0 mils), and the thicknesses of the epoxy adhesive layers 415, 417 are from about 2.54 μm (0.1) to about 20.3 μm (0.8 mils) in the case of homogeneous layers and from about 25.4 μm (1.0) to about 101.6 μm (4.0 mils) in the case of prepreg.

Fig. 5 shows a still further embodiment of a

2S/2P (2 signal plane, 2 power plane) structure incorporating the thin core 501 of the invention. Specifically, the structure shown in Fig. 5 includes one signal core 501. This signal core 501 has two circuitization layers 521a, 521b and may have either the single thermoplastic layer type of structure shown in Fig. 1 or the multiple thermoplastic layer type of structure shown in Fig. 3. Each of the power layers 523a, 523b is separated from the signal core (501) by three adhesive layers 515aa, 515ab, 515ac; 515ba, 515bb, 515bc, such as homogeneous adhesive layers or prepreg (reinforced) layers, with a thermoplastic layer 513aa, 513ab; 513ba, 513bb between each pair of adhesive layers. In the exemplification shown in Fig. 5 the thickness of each of the polyimide thermoplastic layers 513aa, 513ab, 513ba, 513bb is from about 20.3 μm (0.8) to about 50.8 μm (2.0 mils), and the thicknesses of the epoxy adhesive layers 515aa, 515ab, 515ac; 515ba, 515bb, 515bc are from about 2.54 μm (0.1) to about 20.3 μm (0.8 mils) in the case of homogeneous layers and from about 25.4 μm (1.0) to about 101.6 μm (4.0 mils) in the case of prepreg.

Claims

1. An electronic package module (1) adapted to carry surface electric circuitization (21; 321; 421; 521) on a polymeric composite dielectric core (11; 311, 411; 511), comprising a composite having a thermoplastic layer (13, 313a; 213b; 413a, 413b; 513aa, 513ab, 513ba, 513bb) interposed between two separate layers (15, 17; 315a-c; 415a, 415b, 417aa, 417ab, 417ba, 417bb; 515aa-ac, 515ba-bc) of thermoset resin.
2. The electronic package module of claim 1 wherein the thermoplastic layer (13) comprises polyimide, preferably chosen from the group consisting of epoxy resins and cyanate ester resins.
3. The electronic package module of claim 1 or 2 wherein both of the thermoset resin layers are reinforced thermoset resin layers or homogeneous layers.
4. The electronic package module of claim 3 wherein the thickness of the thermoplastic polyimide layer is from about 20.3 μm (0.8) to about 50.8 μm (2.0 mils), and the thicknesses of each of the thermoset resin layers is from about 25.4 μm (1) to about 101.6 μm (4 mils).
5. The electronic package module of claim 3 wherein the reinforcement is chosen from the

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group consisting of woven and nonwoven fiber glass, polytetrafluoroethylene fibers, and organic fibers.

6. A rigid, multilayer electronic circuit package comprising a plurality of circuitized laminated electronic package modules, and having electric signal planes (411e, 411b) and electric power planes (423a, 423b), at least one of said modules being a module according to any one of the preceding claims.
7. A method of fabricating an electronic package module according to any one of the preceding claims 1 to 6, which method comprises laminating the thermoplastic layer between the layers of thermoset resin, and thereafter circuitizing a surface of the thermoset resin.

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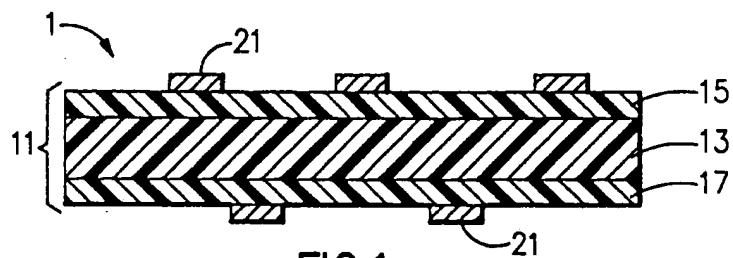
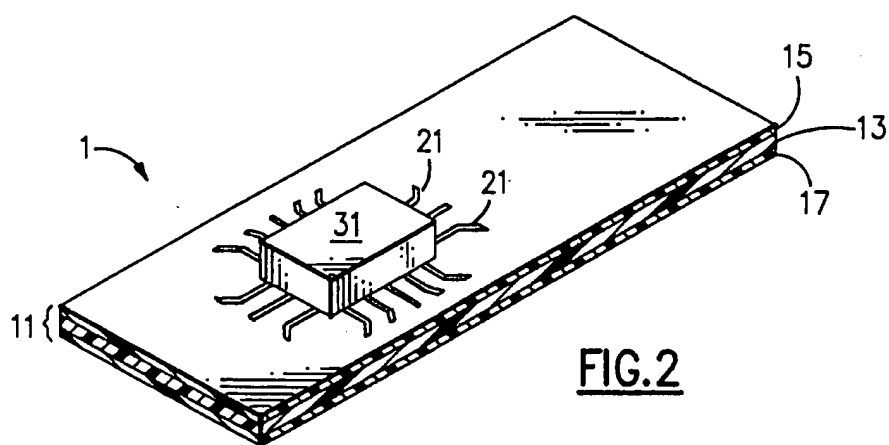
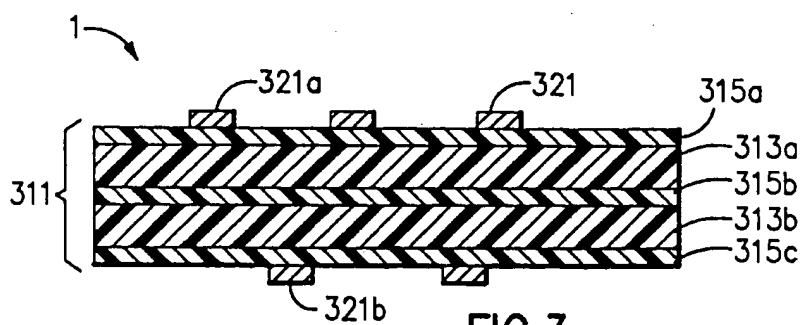
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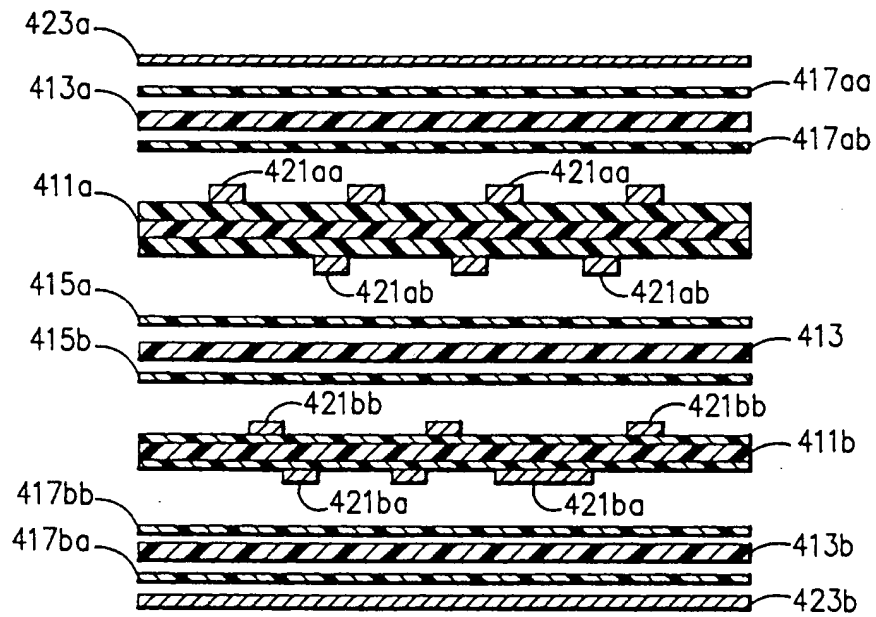
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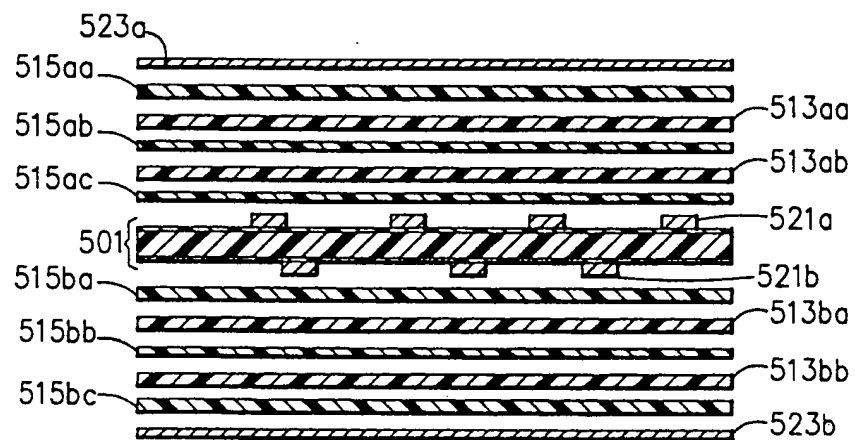
FIG. 1FIG. 2FIG. 3

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FIG. 4

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FIG. 5